



The VERITAS Survey of the Cygnus Region of the Galactic Plane

*University of
California Los Angeles*

A. Weinstein for the VERITAS Collaboration



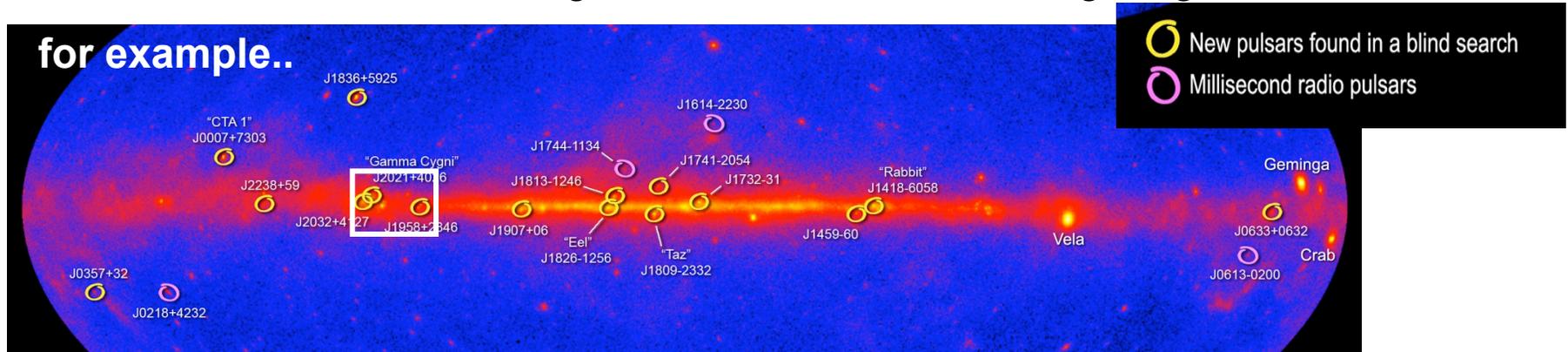
2009 Fermi Symposium

VERITAS Survey of the Cygnus Region
of the Galactic Plane

A. Weinstein, UCLA

Motivation and Context

- Efficient method of searching for new sources over a large region

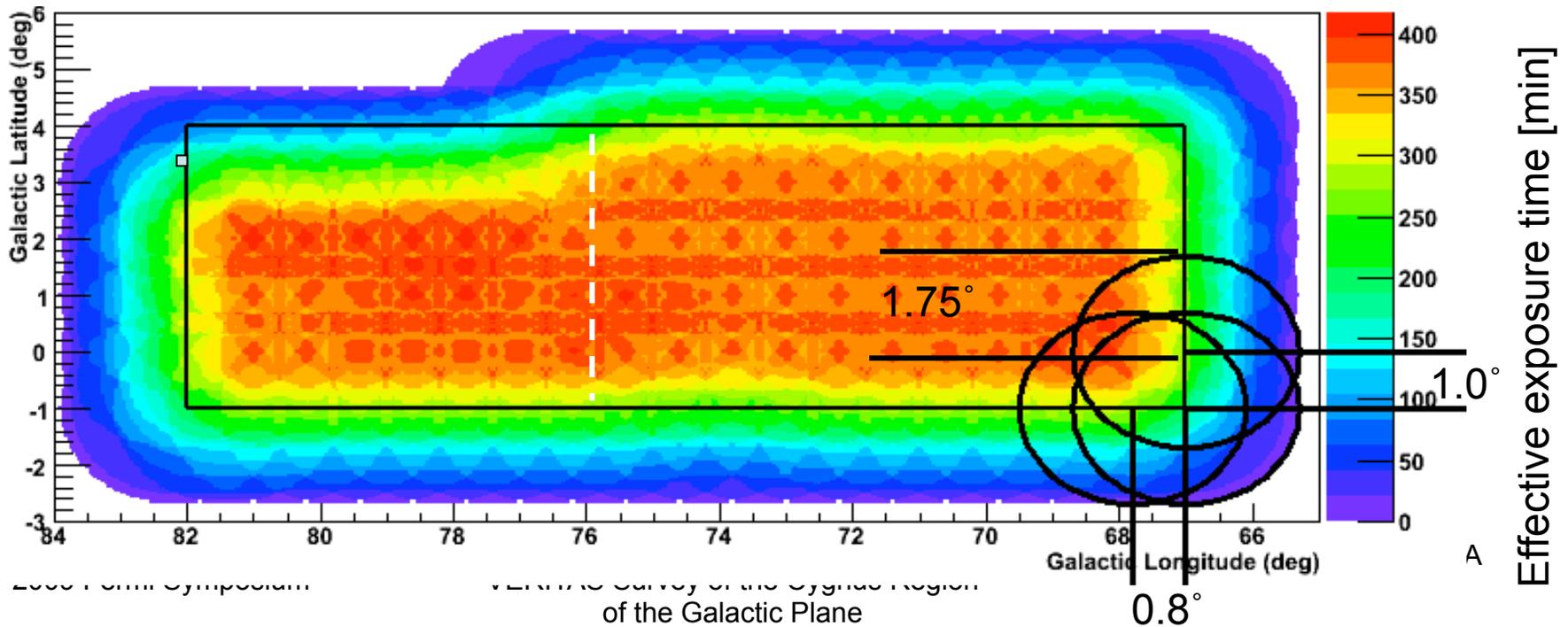
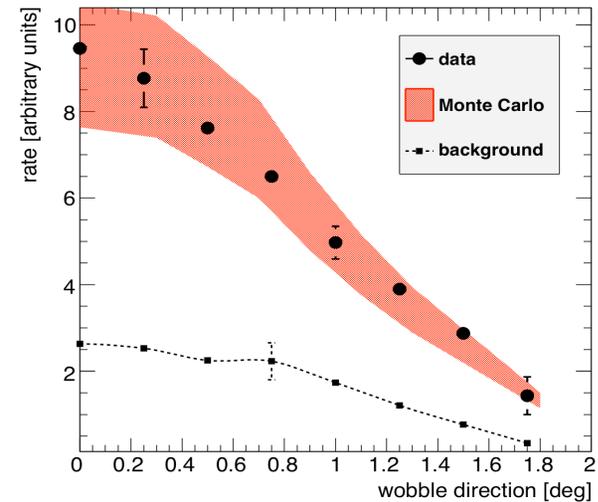


- *Un-biased* indication of source population
- Southern hemisphere well-surveyed
 - HESS Galactic plane survey, ~14 sources in initial survey
- Best limits in northern hemisphere sky : HEGRA's Galactic plane survey
 - $-2^\circ < l < 85^\circ$, flux upper limits: 15% Crab to several Crab
- Size and choice of region based on
 - VERITAS sensitivity and FOV
 - Material distribution, density of potential TeV γ -ray emitters (SNR, PWN, high E-dot pulsars, EGRET unidentified sources..)

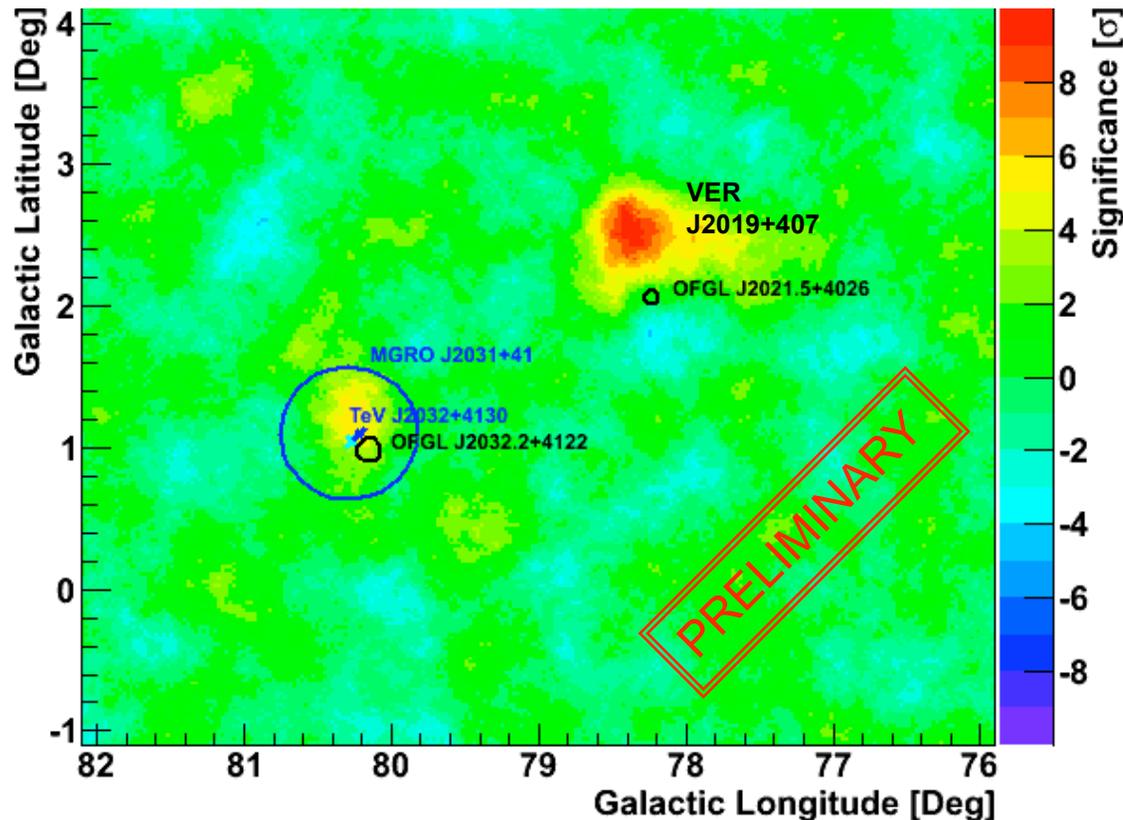
Survey Observation Strategy

Made possible by good VERITAS off-axis sensitivity

- Survey covers region $67^\circ < l < 82^\circ$, $-1^\circ < b < 4^\circ$
- Available observing period: April-June, Sep.-Nov.
- ~6 hrs effective exposure before followup.
- ~112 hours in base survey, ~56 hours followup.



One Interesting Region

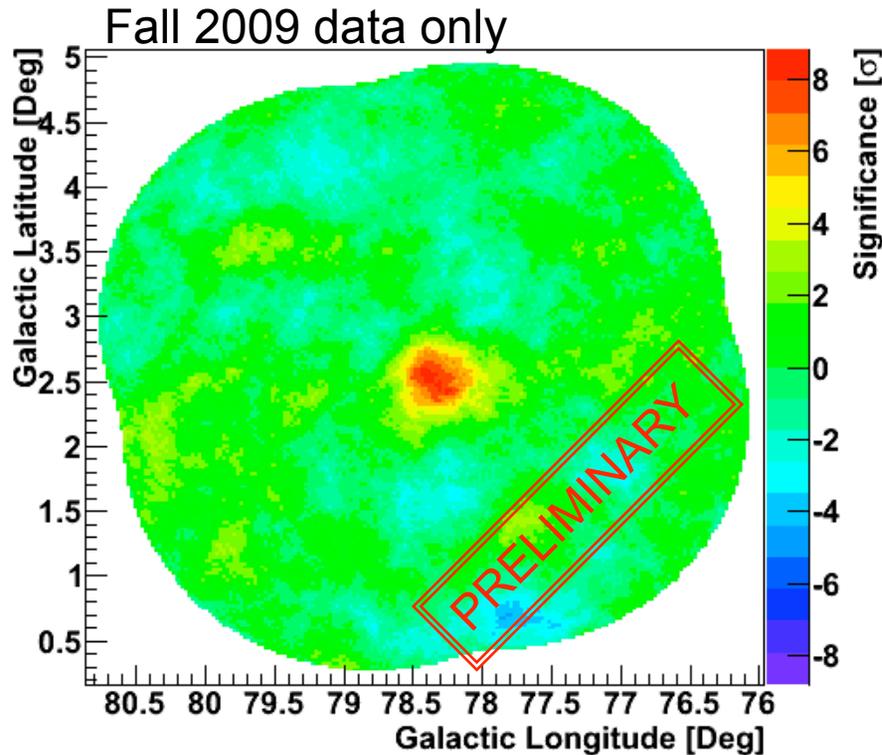


- VER J2019+407
 - New VERITAS source

- TeV J2032+4130
 - known source, first detected by HEGRA
 - Likely associated: MGRO J2031+41, OFGL J2032.2+4122 (LAT pulsar)
 - Detection: $>5\sigma$ at nominal position (no trials)

- Partial survey map, generated with standard threshold extended source analysis
- Includes all data in survey region taken to this point
- Exposure uneven due to followup (more intensive followup around VER J2019+407 than around TeV J2032+4130)

VER J2019+407



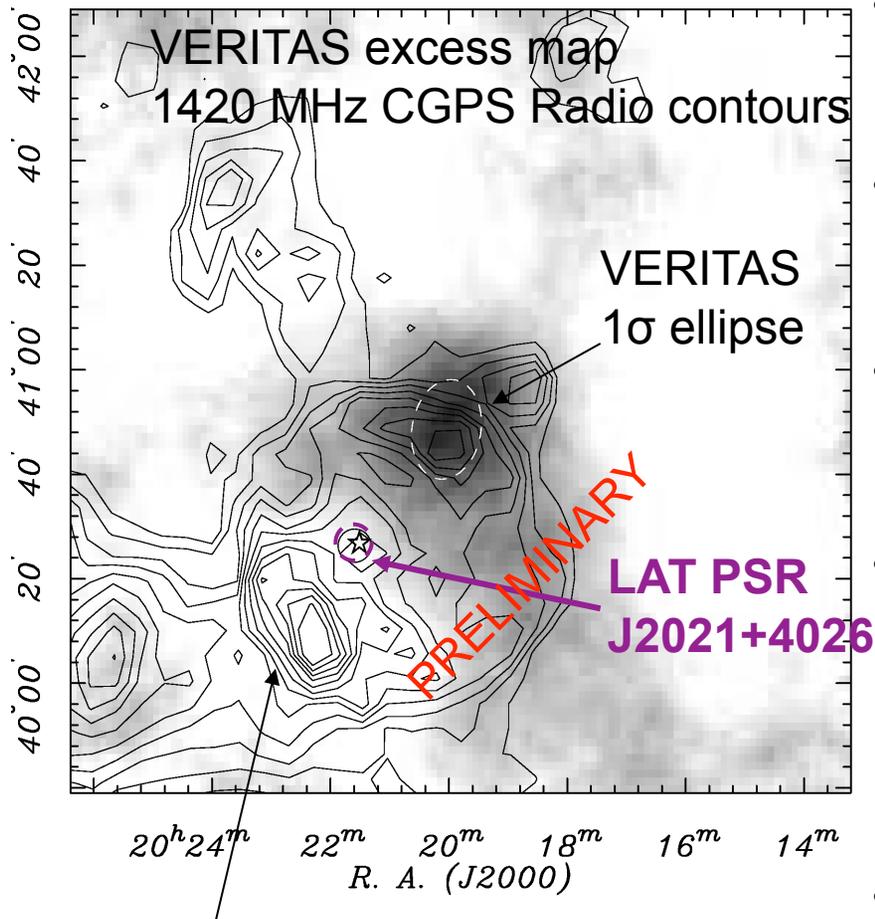
- Early follow-up candidate
- Recent (last six weeks) follow-up treated as an independent search
 - 0.25° radius search region
 - 0.6° wobble, position indicated by earlier data
- 8.5 σ (\sim 7.5 σ) pre-(post-)trials in Fall 2009 data alone;

Preliminary position: RA: 304.97° \pm 0.017°(stat), Dec: 40.79° \pm 0.023°(stat)

Preliminary extension: 0.16° \pm 0.028° (0.11° \pm 0.027°) for the major (minor) axis

- Derived from 2D Gaussian (convolved with VERITAS PSF) fit to uncorrelated excess map (Fall 2009 data only)
- Flux on the order of 2-5% Crab

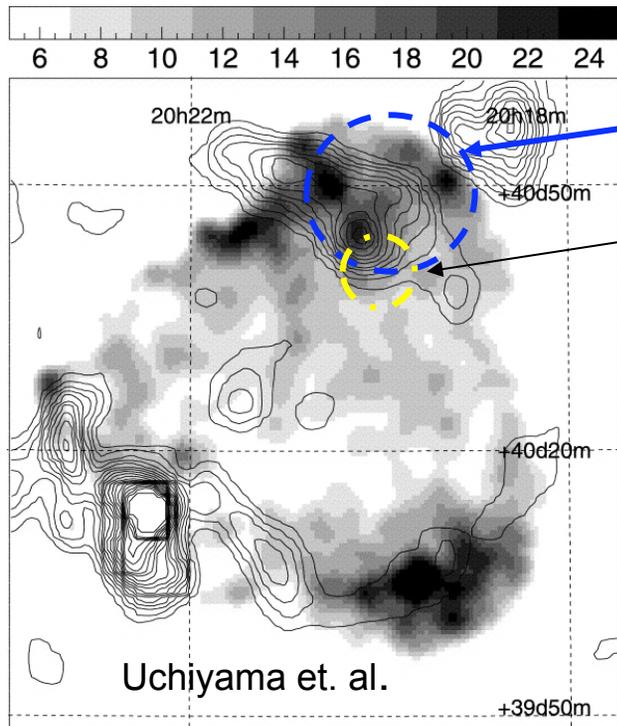
VER J2019+407 in context



No visible emission to the southeast

- In northwest region of Gamma Cygni SNR (G78.2+2.1)
 - What exactly is it?
- PWN?
 - core $\sim 0.5^\circ$ away from Fermi pulsar
 - Association seems unlikely
- VERITAS emission *does* overlap well with radio contours in northwest
- Shock-cloud interaction?
 - Plenty of CO in southeast, not much in northwest
 - Two partial shells in HI, one in northwest (Ladouceur and Pineault 2008, A&A 490, 197)
 - Cloudlets? Enough mass in HI?
- Scenario: SNR was expanding in bubble blown by progenitor star; now hitting dense material in ISM.

VER J2019+407 in context



(a) 0.7-1 keV

ASCA X-ray map
4.85 GHz radio contours

Core of VERITAS excess

In 4-10 keV band, pair of faint hard X-ray sources under core (part of C2, Uchiyama et al.)

- Uchiyama et. al. ApJ, 571:866-875, 2002
 - Soft X-ray emission belt (1-3 keV) from north to southeast
 - shock interacting with cavity wall of ambient clouds?
 - Identifies hard sources in north with shocked dense cloudlets
 - Poss. Ne IX emission lines in soft emission in north
 - Cloudlet density? (need limit on GeV emission)

Cygnus Region: Broad Limits

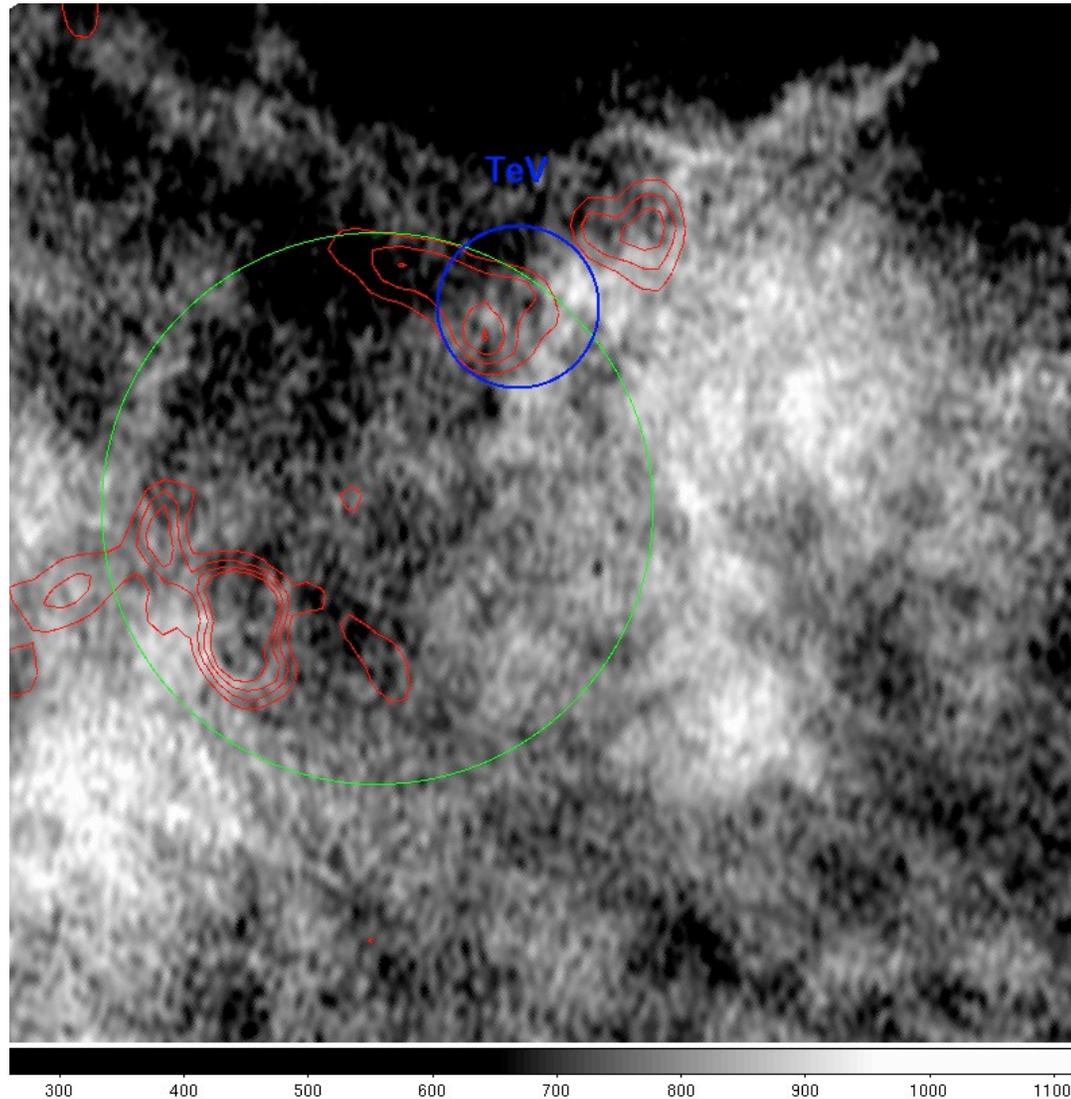
- No hotspots above 5σ post-trials in *base* survey
- Much stronger limits than available in the past from HEGRA
- Preliminary Flux Limits (99% CL, all points in survey below 3σ)
 - $<3\%$ Crab above 200 GeV (point source)
 - $<8.5\%$ Crab above 200 GeV (0.2° radius extended source)
- New un-biased indication of northern hemisphere source population; qualitatively different
 - HESS survey: out of 14 sources in $-30^\circ < l < 30^\circ$, saw 12 sources with fluxes $\geq 5\%$ Crab above 200 GeV

Summary and outlook

- Detection of 2 sources with VERITAS survey technique and followup observations
 - 1 discovery: VER J2019+407
 - TeV J2032
- Further followup observations in survey region ongoing.
- Difference in source density and strength (survey limits, current detections) indicates population difference between northern and southern hemispheres.
- Prospects for future:
 - Spectra and energy-dependent morphology studies (VER J2019+407, TeV J2032).
 - Joint analysis (morphology, cross-correlation studies) with Fermi data in the region.

BACKUP

VER J2019+407 in context



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Analysis Strategy

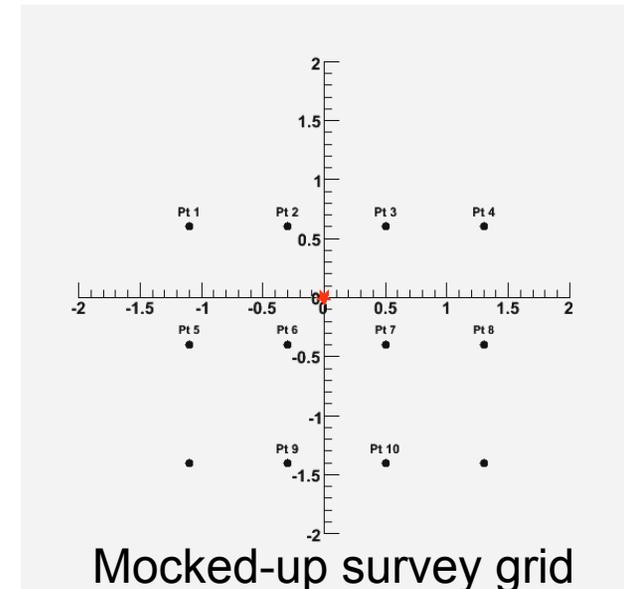
- Data analysis: ring background estimation, four simultaneous, pre-defined analyses

	“Standard” source	“Hard source”
Point source	Size > 90 p.e. $\Theta^2 < 0.013^\circ$	Size cut > 150 p.e. $\Theta^2 < 0.013^\circ$
Extended source	Size > 90 p.e. $\Theta^2 < 0.055^\circ$	Size cut > 150 p.e. $\Theta^2 < 0.055^\circ$

- **Multiple configurations over a 2.5 year period**
 - ~30% of base survey data taken with 3-telescope configuration
 - Spring followup data taken with a different 3-telescope configuration.
 - Most recent followup data taken with new 4-telescope array configuration
- **Zenith angle variation**
 - Range of zenith angles per pointing (affects sensitivity estimates).
 - >80% of all survey pointings are at an average zenith angle <25°.

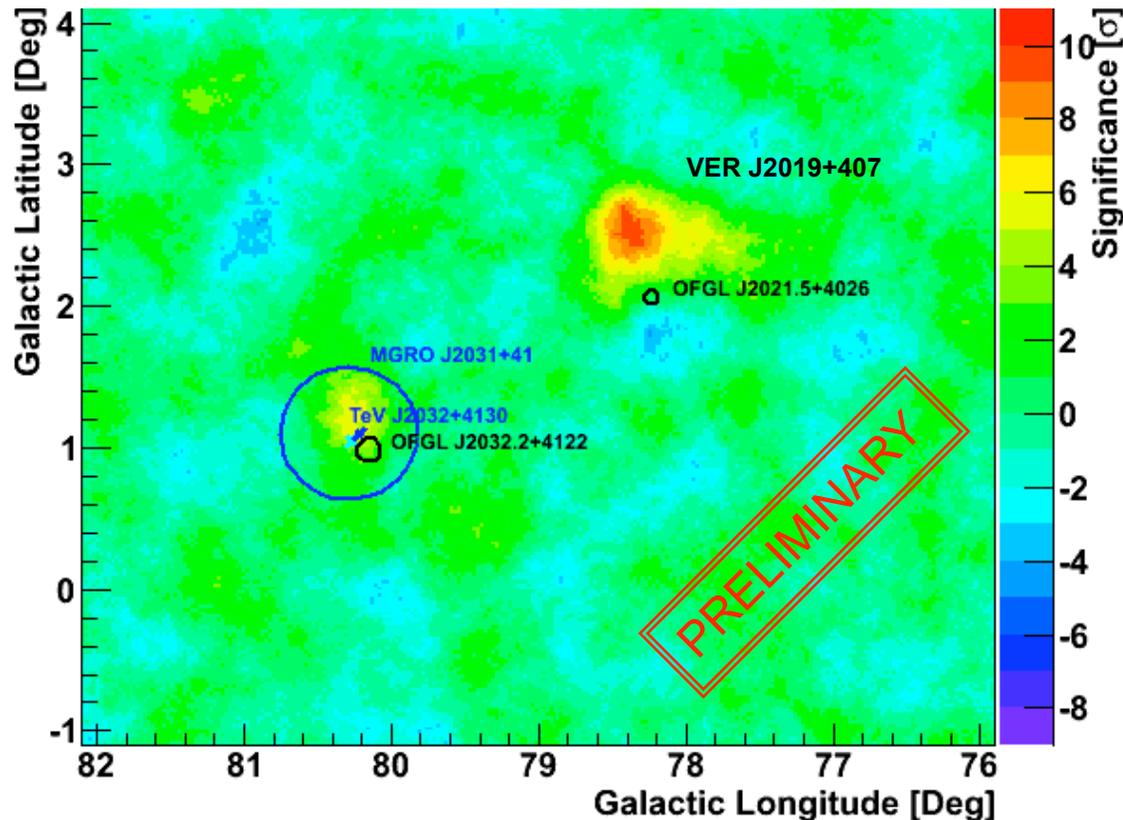
Sensitivity estimation

- Use simulated survey grid
 - average zenith angle of 20°
 - Blank survey fields for background
 - Inject simulated photons (spectra between 2.5 and 2.0, varied source extent)
- Estimates are
 - Conservative (zenith angle, configuration variations)
 - Consistent with standard VERITAS sensitivity curves/ calculated “effective” exposure time.
- Sensitivity estimates based on achieving $>5\sigma$ pre-trials (trigger for followup)



Analysis type	Spectral Index	Extension	Flux (Crab > 200 Gev)
Std point	2.5 (2.0)	None	<0.04
Std extended	2.5 (2.0)	0.2° gaussian radius	<0.1
			Flux (Crab > 500 Gev)
Hard point	2.0	None	<0.063
Hard extended	2.0	0.2° gaussian radius	<0.16

One Interesting Region



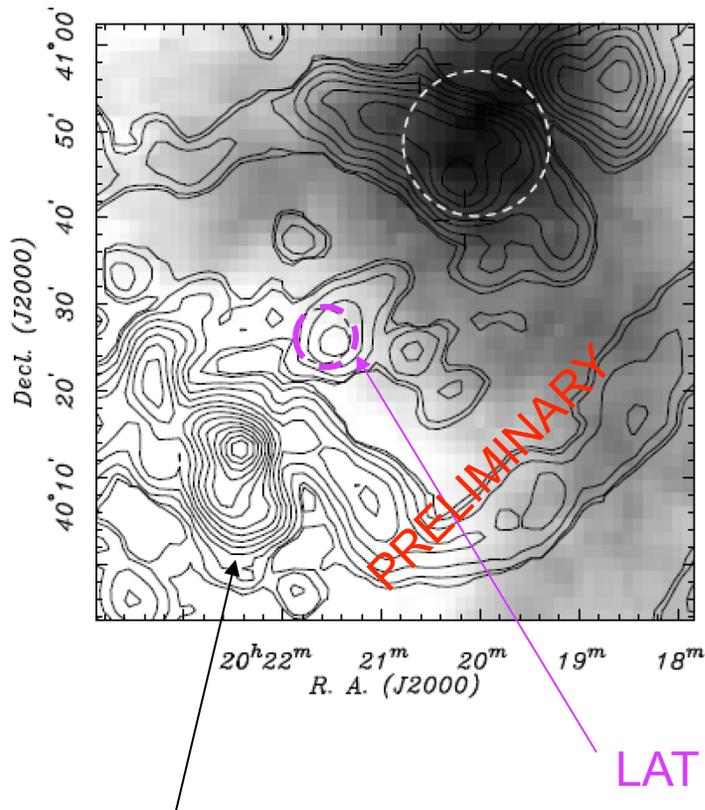
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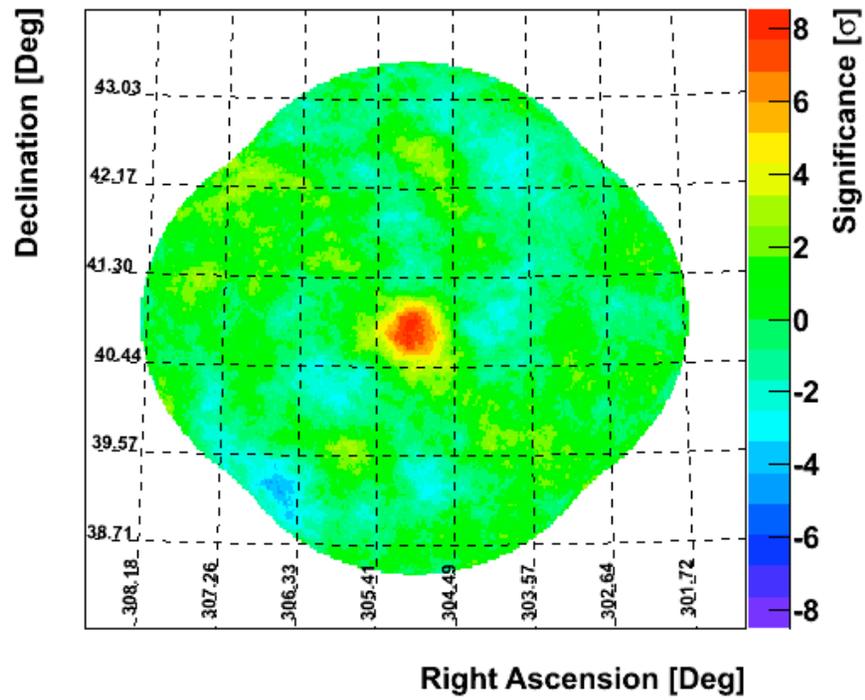
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VERITAS excess
4.85 GHz NRAO Radio contours



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 - Association seems unlikely
- Shock-cloud interaction?
 - VERITAS emission overlaps well with radio contours in the northwest



VERITAS at Whipple Observatory



Instrument design:

- Four 12-m telescopes
- 499-pixel cameras (3.5° FoV)
- FLWO, Mt. Hopkins, Az (1268 m)

Specifications:

- Angular resolution $\sim 0.1^\circ$ (1 TeV)
- Energy resolution $\sim 15\text{-}20\%$

T1 position
Fall 2006 –
Spring 2009

82 m

109 m

T1 position
Fall 2009

Prior Sensitivity:

- 1% Crab @ 5σ  50 hrs
- 5% Crab @ 5σ  ~ 2.5 hrs

Fall 2009 Sensitivity:

- 1% Crab @ 5σ  30 hrs

